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(54) **DEVICE AND METHOD FOR ADAPTIVELY SUPPRESSING IN-BAND INTERFERENCE SIGNALS IN RADIO RECEIVERS**

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H04B 1/71 (2011.01)
H04B 1/28 (2006.01)

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CPC ***H04B 1/7101*** (2013.01); ***H04B 1/1036*** (2013.01); *H04B 1/109* (2013.01); ***H04B 1/28*** (2013.01); *H04B 2001/1072* (2013.01)

(58) **Field of Classification Search**
USPC 375/134
See application file for complete search history.

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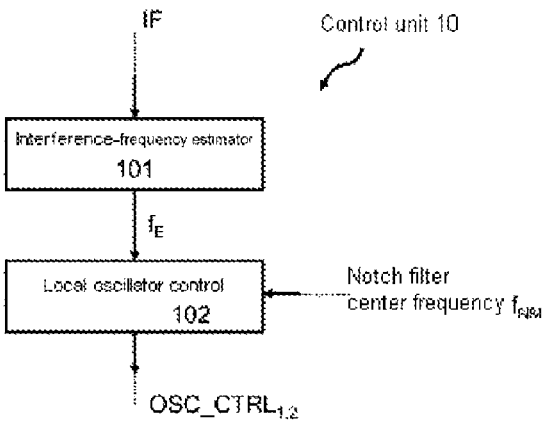
(57) **ABSTRACT**

A circuit arrangement for adaptively suppressing interference signals includes a first local oscillator for generating a first local oscillator signal and a second local oscillator for generating a second local oscillator signal, each signal having an adjustable frequency. The circuit arrangement also includes a first mixer for converting a high-frequency signal into a corresponding intermediate frequency signal using the first local oscillator signal and a second mixer for converting the intermediate frequency signal into a corresponding baseband signal using the second local oscillator signal. The circuit arrangement also includes a notch filter with a rigidly defined blocking range. A control unit estimates the frequency of an interference signal contained in the intermediate frequency signal and to adjust the frequency of the local oscillator signals to the estimated frequency of the interference signal such that the frequency of the interference signal is converted into the blocking range of the notch filter.

16 Claims, 3 Drawing Sheets



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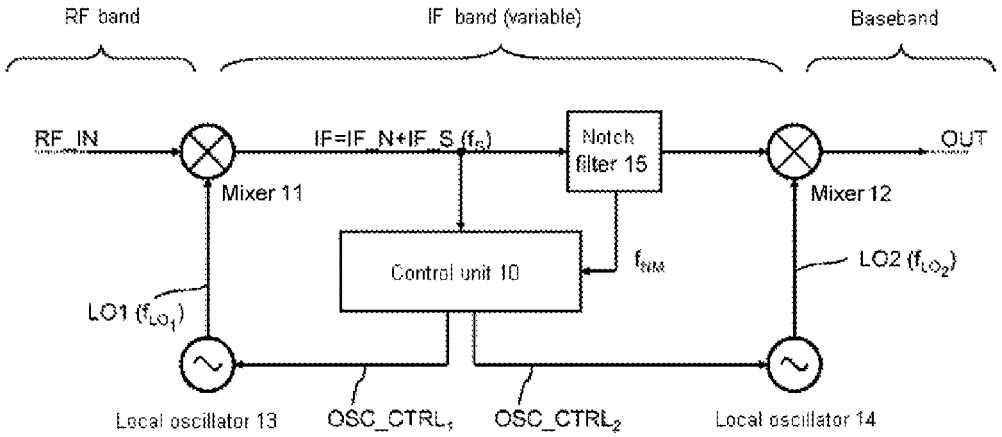
RF band
IF band (variable)
Baseband
RF_IN
IF=IF_N+IF_S (f_S)
Notch filter 15
OUT
Mixer 11
Mixer 12
Control unit 10
f_{NM}
LO2 (f_{LO_2})
LO1 (f_{LO_1})
Local oscillator 13
OSC_CTRL$_1$
OSC_CTRL$_2$
Local oscillator 14

Fig. 1

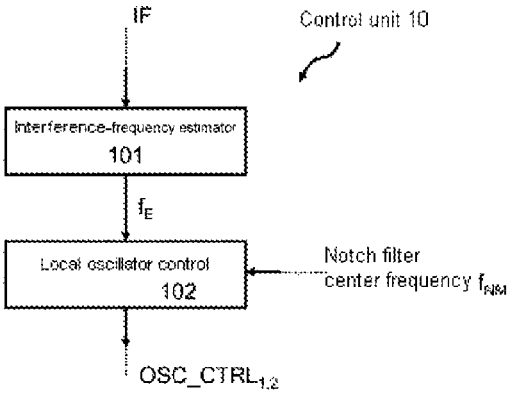
IF
Control unit 10
Interference-frequency estimator
101
f_E
Local oscillator control
102
Notch filter
center frequency f_{NM}
OSC_CTRL$_{1,2}$

Fig. 2

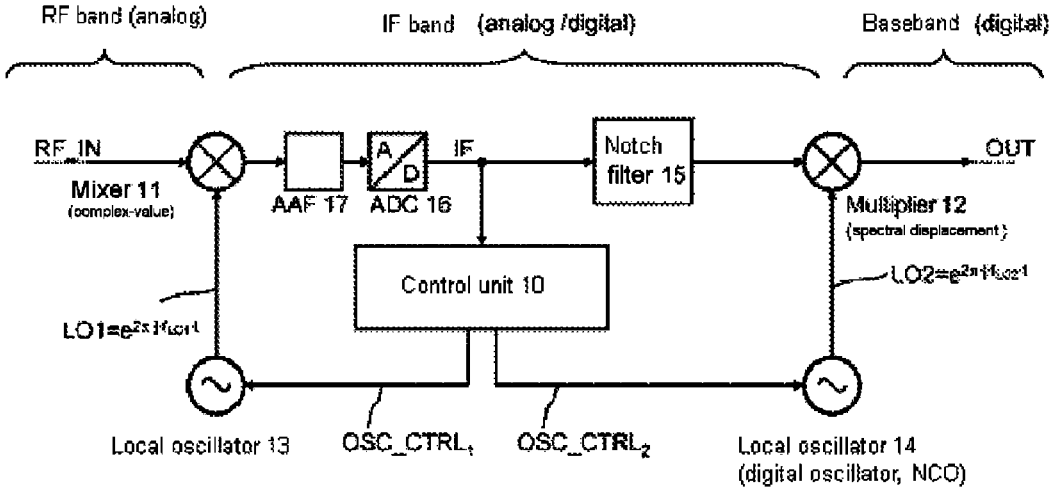
RF band (analog)
IF band (analog /digital)
Baseband (digital)
RF_IN
Mixer 11
(complex-value)
AAF 17
A/D
ADC 16
IF
Notch filter 15
OUT
Multiplier 12
(spectral displacement)
Control unit 10
LO1=e^{2πjf_LO1t}
LO2=e^{2πjf_LO2t}
Local oscillator 13
OSC_CTRL1
OSC_CTRL2
Local oscillator 14
(digital oscillator, NCO)

Fig. 3

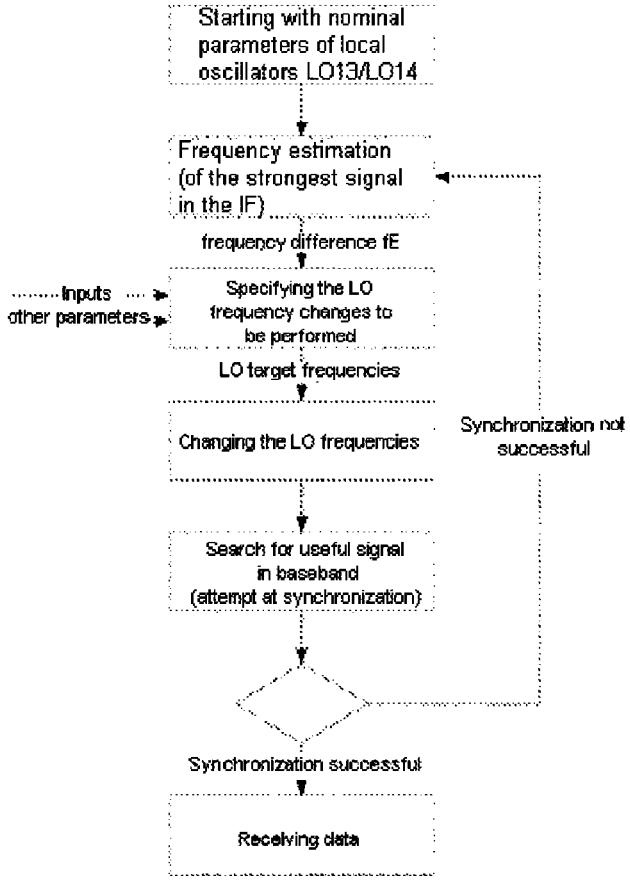
Starting with nominal parameters of local oscillators LO13/LO14
Frequency estimation (of the strongest signal in the IF)
frequency difference fE
Inputs
other parameters
Specifying the LO frequency changes to be performed
LO target frequencies
Changing the LO frequencies
Synchronization not successful
Search for useful signal in baseband (attempt at synchronization)
Synchronization successful
Receiving data

Fig. 4

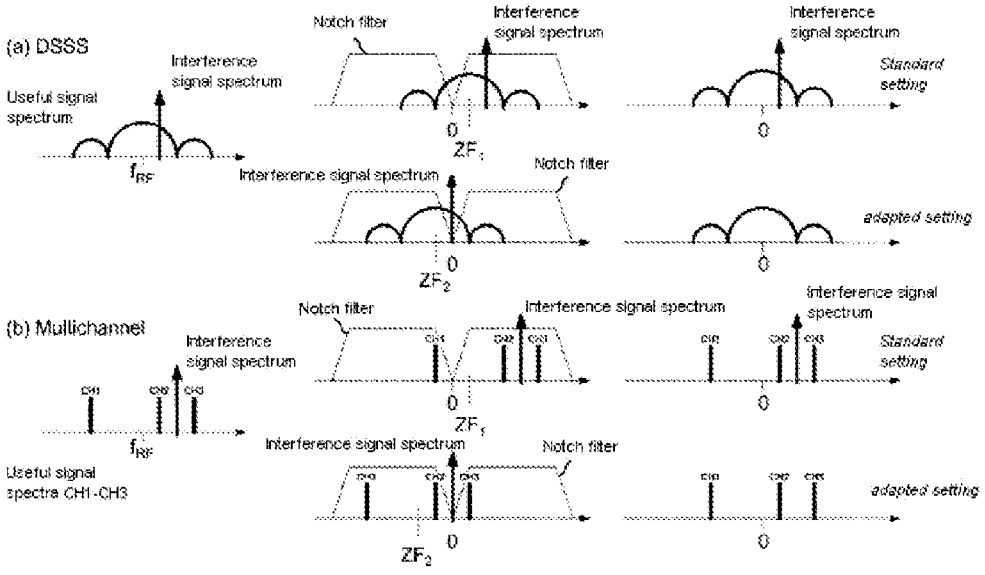
(a) DSSS
Useful signal spectrum
Interference signal spectrum
f_{RF}
Notch filter
Interference signal spectrum
0
ZF_1
Interference signal spectrum
Standard setting
0
Interference signal spectrum
Notch filter
0
ZF_2
adapted setting
0
(b) Multichannel
Interference signal spectrum
CH1
CH2
CH3
f_{RF}
Useful signal spectra CH1-CH3
Notch filter
Interference signal spectrum
0
ZF_1
Interference signal spectrum
Standard setting
0
Interference signal spectrum
Notch filter
0
ZF_2
adapted setting
0

Fig. 5

DEVICE AND METHOD FOR ADAPTIVELY SUPPRESSING IN-BAND INTERFERENCE SIGNALS IN RADIO RECEIVERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Stage Application of International Application No. PCT/EP2012/059034 filed May 15, 2012, which designates the United States of America, and claims priority to DE Application No. 10 2011 075 893.3 filed May 16, 2011, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present invention relates to the suppression of interference signals in the useful signal band in radio receivers.

BACKGROUND

Frequently, narrow-band interference signals are suppressed in radio receivers with the aid of band-stop filters. Narrow-band band-stop filters are also called notch filters. In spread-spectrum transmission methods, in particular, notch filters can be used for suppressing narrow-band interference signals (e.g. in a direct sequence spread spectrum (DSSS) receiver). Due to the frequency spreading of the useful signal, a narrow-band notch in the (spread) useful signal does not have a significant effect on the useful signal after despreading.

The frequency of an interference signal is not known a priori. Since a wide-band filtering will render the useful signal unuseable, only narrow-band filtering can be considered. For this purpose, the frequency of the interference signal can be determined and the frequency response of the notch filter can be adapted correspondingly so that the (narrow-band) stop band of the notch filter hits the interference signal. Such radio receivers plus notch filters with adaptively adaptable stop band are known, e.g., from the American patent document U.S. Pat. No. 7,706,769. However, notch filters having a stop band adaptable (in accordance with an input) are expensive to implement.

SUMMARY

One embodiment provides a circuit arrangement for suppressing interference signals with the aid of a band-stop filter; the circuit arrangement having the following features: a first local oscillator and a second local oscillator for generating a first local oscillator signal and a second local oscillator signal, respectively, with a respectively adjustable frequency; a first mixer for converting a radio-frequency signal into a corresponding intermediate-frequency signal as determined by the first local oscillator signal with adjustable frequency; a second mixer for converting the intermediate-frequency signal into a corresponding baseband signal as determined by the second local oscillator signal with adjustable frequency; a notch filter having a stop band defined by a predetermined frequency response; and a control unit which is designed for estimating the frequency of an interference signal contained in the intermediate-frequency signal and which is also designed for adapting the frequency of the local oscillator signals to the estimated frequency of the interference signal in such a manner that the frequency of the interference signal lies within the stop band of the notch filter.

In a further embodiment, the control unit has: a frequency estimator which is designed for estimating the frequency of an interference signal contained in the intermediate-frequency signal, and a local oscillator control which is designed for determining the frequency difference between the estimated frequency and the center frequency of the stop band of the notch filter and adapting the frequencies of the local oscillator signals in accordance with the frequency difference determined.

In a further embodiment, the circuit arrangement has an analog/digital converter after the first mixer in the direction of signal for digitizing the intermediate-frequency signal, and wherein at least the control unit, the second mixer and the second local oscillator are implemented digitally.

In a further embodiment, the circuit arrangement further includes an antenna and a radio-frequency receiving circuit connected to the antenna, which provides as radio-frequency signal an antenna signal received from the antenna.

In a further embodiment, the received radio-frequency signal is a wideband, modulated spread-spectrum signal and which also has a unit for despreading the baseband signal.

Another embodiment provides a method for receiving a radio-frequency signal which comprises the following: converting the radio-frequency signal from an RF band into an intermediate-frequency band by mixing the radio-frequency signal with a first local oscillator signal in order to thus obtain a corresponding intermediate-frequency signal; estimating an interference signal frequency of an interference signal contained in the intermediate-frequency signal; filtering the intermediate-frequency signal with a notch filter having a stop band; and adapting the frequencies of the local oscillator signal to the estimated frequency of the interference signal in such a manner that the frequency of the interference signal lies within the stop band of the notch filter.

In a further embodiment, the method further includes: converting the intermediate-frequency signal from the intermediate-frequency band into a baseband by means of a second local oscillator signal in order to thus obtain a corresponding baseband signal; searching for a useful signal in the baseband signal; and receiving the data contained in the useful signal when a useful signal has been found.

In a further embodiment, the method further includes repeating the preceding method steps when no useful signal has been found.

In a further embodiment, searching for a useful signal in the baseband signal comprises despreading the baseband signal by means of a known spreading sequence.

In a further embodiment, the intermediate-frequency signal is digitized before or after the filtering with the notch filter.

In a further embodiment, the notch filter is inactive during the estimating of the interference-signal frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the invention are explained in greater detail below with reference to the drawings, in which:

FIG. **1** shows in a block diagram a circuit arrangement for adaptively suppressing interference signals by means of a notch filter which operates in the intermediate-frequency band;

FIG. **2** shows in a block diagram a control circuit for use in the circuit arrangement according to FIG. **1**;

FIG. **3** shows in a block diagram the circuit arrangement from FIG. **1** but with partially digital implementation;

FIG. **4** shows in a flowchart a method for receiving radio signals in which narrow-band interference signals are adaptively suppressed; and

FIG. **5** shows an example effect of one embodiment using diagrams that represent the spectra of useful signal and interference signal in the radio-frequency band, in the intermediate-frequency band and in the baseband.

DETAILED DESCRIPTION

Embodiments of the invention provide an arrangement and a method for adaptively suppressing in-band interference signals for the application in radio receivers, which can be implemented with the least possible (hardware and software) expenditure.

For example, a circuit arrangement for adaptively suppressing interference signals is described. The circuit arrangement has a first local oscillator for generating a first local oscillator signal and a second local oscillator for generating a second local oscillator signal having in each case an adjustable frequency. The circuit arrangement also comprises a first mixer for converting a radio-frequency signal into a corresponding intermediate-frequency signal as determined by the first local oscillator signal, and a second mixer for converting the intermediate-frequency signal into a corresponding baseband signal as determined by the second local oscillator signal. Finally, the circuit arrangement comprises a notch filter having a predetermined stop band. A control unit is designed for estimating the frequency of an interference signal contained in the intermediate-frequency signal and adapting the frequency of the local oscillator signals to the estimated frequency f_S of the interference signal in such a manner that the frequency f_S of the interference signal is converted into the stop band of the notch filter.

Also disclosed is a method for suppressing an interference signal in a useful signal and a radio receiver in which the abovementioned circuit arrangement is applied.

FIG. **1** shows an exemplary circuit arrangement, as shown simplified, for adaptively suppressing interference signals with the aid of a notch filter. Such a circuit arrangement can be used, for example, in a radio receiver (especially in its radio-frequency front-end unit) and, for example, in receivers of keyless access systems.

A radio-frequency input signal RF_IN (also called RF signal RF_IN in the text that follows), coming, for example, from a receiving antenna or a directional coupler, is supplied to an input of a first mixer **11**. A first local oscillator **13** generates the local oscillator signal LO**1**, necessary for operating the mixer, with adjustable frequency f_{LO1}. The mixer converts the radio-frequency signal RF_IN into an intermediate-frequency signal (IF signal) IF. This intermediate-frequency signal IF is located in another, in most cases lower, frequency band (intermediate-frequency band=IF band) than the radio-frequency signal. In this context, the spectrum of the useful signal contained in the radio-frequency signal RE_IN is only displaced, if possible, but not altered, so that the information contained in the useful signal is not lost. The amount of this frequency displacement is determined by the frequency f_{LO1} of the local oscillator signal LO**1** which is supplied to the mixer **11**, in addition to the radio-frequency signal RF_IN. As a rule, the spectral position of the intermediate-frequency signal is determined with the circuit concept. In the present example, the frequency f_{LO1} of the local oscillator signal LO**1** is adjustable and, in consequence, the spectral position of the IF band can be adjusted by varying the frequency f_{LO1} of the corresponding local oscillator **13**. The bandwidth of the intermediate-frequency signal must cover at least the spectrum of the useful signal but it can also be distinctly wider than the bandwidth of an individual useful signal in order to be able to process, for example, a number of channels in parallel in the intermediate-frequency band (e.g. digitally).

The intermediate-frequency signal IF is converted into a baseband with the aid of a second mixer **12** and a second local oscillator signal LO**2**, generated by a second local oscillator **14**, having a frequency f_{LO2}, with a resultant baseband signal OUT for further processing by subsequent units. For example, when using a DSSS (Direct Sequence Spread Spectrum) transmission method, the despreading of the signal which is spread at the transmitter before the transmission takes place in the baseband.

In the intermediate-frequency band, signal preprocessing can take place, in particular, the intermediate-frequency signal IF can be filtered. In order to suppress, for example, a narrow-band interference signal IF_S, which occurs in the intermediate-frequency signal IF in addition to a useful signal IF_N (IF=IF_N+IF_S) having a center frequency f_S, the intermediate-frequency signal IF can be filtered with the aid of a notch filter **15**. The interference signal IF_S is suppressed at the precise moment when its frequency f_S is in the stop band of the notch filter **15**. For this purpose, the spectral position of the stop band should be adapted to the frequency f_S of the interference signal. The frequency f_S of the interference signal IF_S is not known a priori or can vary. According to the example shown in FIG. **1**, however, a notch filter **15** with predetermined characteristic, i.e. fixed stop-band center frequency, which is simple to implement, is used, i.e. the spectral position of the stop band is predetermined and is not variable. Instead of adapting the filter characteristic of the notch filter **15**, the intermediate-frequency signal IF, thus also any interference signal IF_S contained therein, is shifted in frequency with the aid of the first mixer **11** in such a manner that the frequency f_S of the interference signal IF_S contained in the intermediate-frequency signal IF comes to be located precisely within the stop band of the notch filter **15**. The interference signal IF_S contained in the intermediate-frequency signal IF can thus be shifted in frequency by varying the local oscillator signal LO**1** supplied to the mixer **11**.

For this purpose, a control unit **10** is provided, for example, which is supplied with the intermediate-frequency signal IF and which is designed for estimating, on the basis of the intermediate-frequency signal IF, the frequency f_S of the interference signal IF_S contained in the intermediate-frequency signal IF, resulting in an estimated interference signal frequency f_S'. If the estimated frequency f_S' of the interference signal is outside the stop band of the notch filter **15**, the first local oscillator signal LO**1** is correspondingly adapted in order to displace the intermediate-frequency signal IF. In addition, a corresponding adaptation of the second local-oscillator signal LO**2** is provided in order to keep the entire frequency displacement from the radio-frequency band (RF band) into the baseband constant. This adaptation of the local oscillator signals is carried out in the present example with the aid of the control signals OSC_CTRL_1 and OSC_CTRL_2, respectively.

In FIG. **2**, the control unit **10** used by way of example in the arrangement according to FIG. **1** is shown in greater detail. The control unit **10** comprises at least one frequency estimator **101** and one local oscillator control **102**. The frequency estimator **101** is designed for estimating the frequency f_S of the possibly present interference signal IF_S from the intermediate-frequency signal IF. The frequency difference f_E between the estimated interference signal frequency f_S' and the center frequency f_{NM} of the stop band of the notch filter **15** is the value by which the frequency of oscillation f_{LO1} of the first local oscillator signal LO**1** ($f_E=f_S'-f_{NM}$) would have to be

corrected so that the interference signal frequency f_S is located precisely in the center of the stop band of the notch filter **15** and is thus maximally attenuated. That is to say when the interference signal frequency f_S is precisely (or with a certain tolerance) in the center of the stop band of the notch filter **15**, the frequency difference f_E is zero. Suitable methods for estimating the interference signal frequency f_S or the frequency difference f_E are sufficiently known.

With the aid of the frequency estimator **101**, the deviation in the form of the frequency difference f_E of the interference signal frequency f_S from the center frequency f_{NM} of the stop band of the notch filter **15** can thus be determined directly or indirectly. The local oscillator control **102** is designed for adapting the current local oscillator frequencies f_{LO1} and f_{LO2} of the two local oscillators **13** and **14** in accordance with the estimated frequency difference f_E. This means that the frequency f_{LO1} of the first local oscillator signal LO**1** is increased by the estimated frequency difference f_E and the frequency f_{LO2} of the second local oscillator signal LO**2** is reduced by the estimated frequency difference f_E. After this adaptation, the interference signal frequency f_S is located precisely in the center of the stop band of the notch filter **15** and the interference signal IF_S is suppressed in the best possible way.

In this context, parts of the circuit arrangement shown in FIG. **1** can be implemented with the aid of a system for digital signal processing. An example of this is shown in FIG. **3**. The arrangement shown in FIG. **3** corresponds in its basic function to that from FIG. **1**, with the difference that (in the direction of signal flow) a digitization of the intermediate-frequency signal IF is performed by means of analog/digital converters **16** after the first mixer **11** and the remaining signal processing is carried out, for example, with the aid of a digital signal processor and corresponding software. Thus, at least the notch filter **15** and the control unit **10** are implemented digitally. Furthermore, the second mixer **12** is also implemented as digital multiplication (for the spectral displacement of the intermediate-frequency signal IF into the baseband) of the filtered intermediate-frequency signal IF by the second local oscillator signal LO**2**. The second local oscillator signal LO**2** is then generated, for example, by a so-called NCO (numerically controlled oscillator), that is to say a digital oscillator.

In the illustrations of FIGS. **1** and **2**, components which are not necessary for explaining the operation of the circuit arrangement have been omitted for the sake of simplicity, but can be added arbitrarily in a suitable manner such as, e.g., amplifiers, anti-aliasing filters, sampling rate converters, other filters, etc.

The notch filter **15** can also be implemented as a combination of a number of part-filters. In the example of FIG. **3**, a part of the filter transfer function of the notch filter **15** could also be implemented in the form of an analog filter. In particular, the transfer function of an anti-aliasing filter connected before the analog/digital converter **16** could be selected such that this (also) operates as notch filter. Depending on the technology selected for the implementation, the notch filter can also be implemented in a completely analog manner. With a purely digital implementation, filter transfer functions used in any case, for example, in the digital signal processing path of a receiver can be modified in such a manner that the desired notch filter transfer function is implemented. A filter present in any case for correcting errors in magnitude and phase between the in-phase and quadrature signal components could be used, e.g., for this purpose. In the simplest case, the notch filter is a simple high-pass filter (for the case that the interference signal is mixed to zero frequency), which can also be called a DC notch filter. Optionally, the notch filter can be deactivated during the frequency estimation in order to avoid interference signals from being covered during the estimation.

Various methods are known for the actual frequency estimation. A minimum variance estimator which is true to the expectation for the interference signal frequency is, for example,

$$f_s' = \frac{f_s}{2\pi} \sum_{k=1}^{L_0-1} \gamma(k) \arg\{z(k) z^*(k)\}, \tag{1}$$

where the smoothing function $\gamma(k)$ is calculated as follows:

$$\gamma(k) = \frac{3}{2} \frac{L_0}{L_0^2 - 1} \left[1 - \left(\frac{2k - L_0}{L_0} \right)^2 \right]. \tag{2}$$

The variable f_S here designates the sampling frequency, z(k) the sample at sampling time k, z*(k) the conjugate complex sample at sampling time k−1, and the parameter L_0 designates the number of samples which are processed for an estimation (compare U. Mengali, A. N. D'Andrea: Carrier Frequency Recovery with Linear Modulations (Chapter 3), In: Synchronization Techniques for Digital Receivers, Plenum Press, New York, 1997).

FIG. **4** shows a flowchart of a method for receiving radio signals in which narrow-band interference signals are adaptively suppressed with the aid of the circuit arrangements from FIG. **1** or **3**.

Firstly, the frequency f_S of the interference signal IF_S is estimated, the local oscillator signals LO**1** and LO**2**, and thus the position of the intermediate-frequency band, having nominal (i.e. predetermined standard) values. From the estimated interference signal frequency f_S, the frequency difference f_E can be determined, with the consequence that the interference signal contained in the intermediate-frequency signal IF is not within the stop band of the notch filter. Following this, the local oscillator frequencies f_{LO1} and f_{LO2} are adapted by the frequency difference f_E determined so that the intermediate-frequency band shifts by the frequency value f_E and the interference signal IF_S comes to lie precisely within the stop band of the notch filter **15**.

Following this, the baseband can be searched for the useful signal (i.e. for coded information). If this search is successful, the data contained in the useful signal can be received. If not, it is attempted again to estimate the interference signal frequency f_S and the method described begins anew until proper data reception is possible.

The decision whether an adaptation of the local oscillator frequencies f_{LO1}, f_{LO2} is actually performed can also be made dependent on other (e.g. externally determined) parameters. For example, "forbidden" frequency bands can be predetermined for the local oscillator control in which this should not be impaired at all by notch filtering. Furthermore, a minimum level (received signal strength indicator level, RSSI level) can be predetermined which the interference signal must have in order to be recognized as such.

FIG. **5** diagrammatically shows an example effect of one embodiment using a DSSS signal (FIG. **5***a*) as useful signal and for the case of a number of (narrow-band) useful signals of different channels (FIG. **5***b*). In both cases, the spectrum of the useful signal (or of the useful signals of several channels) can be seen on the left in the radio-frequency band, the corresponding spectrum can be seen in the center in the interme-

diate-frequency band and the resulting spectrum can be seen on the right in the baseband. In both figures (FIGS. **5***a* and **5***b*) two variants are shown, the first variant (intermediate-frequency signal IF_1) in each case showing the local-oscillator setting to nominal values, and the second variant (intermediate-frequency signal IF_1) showing the adapted state in which the interference signal spectrum is located in the stop band of the notch filter.

In the standard setting, the interference signal cannot be eliminated by the notch filter since the interference signal spectrum can virtually lie anywhere within the intermediate signal and does not have to lie within the stop band of the notch filter. According to the described example embodiments, the intermediate-frequency signal is displaced spectrally by adaptation of the local oscillator frequencies in such a manner that the spectrum of the interference signal comes to lie precisely within the stop band of the notch filter. In the present example, the notch filter is a so-called DC notch filter, i.e. the center frequency is zero.

In the text which follows, some aspects of embodiments of the invention are summarized again without claiming completeness. One example embodiment provides a circuit arrangement for suppressing interference signals with the aid of a band-stop filter. The circuit arrangement can have the following components: a first local oscillator **13** and a second local oscillator **14** for generating a first local oscillator signal LO**1** and a second local oscillator signal LO**2**, respectively, with a respectively adjustable frequency f_{LO1} and f_{LO2}, respectively; a first mixer **11** for converting a radio-frequency signal RF_IN into a corresponding intermediate-frequency signal IF as determined by the first local oscillator signal LO**1**; a second mixer **12** for converting the intermediate-frequency signal IF into a corresponding baseband signal OUT as determined by the second local oscillator signal LO**1**; a notch filter **15** having a stop band defined by a predetermined frequency response; and a control unit **10** which is designed for estimating the frequency f_S of an interference signal IF_S contained in the intermediate-frequency signal IF and which is also designed for adapting the frequency f_{LO1}, f_{LO2} of the local oscillator signals LO**1**, LO**2** to the estimated frequency f_S of the interference signal IF_S in such a manner that the frequency f_S of the interference signal lies within the stop band of the notch filter **15**. Such a circuit arrangement allows a notch filter having a fixed frequency response to be used. No filters adaptable in their frequency response are needed in the intermediate-frequency band.

The control unit **10** can have a frequency estimator **101** which is designed for estimating the frequency f_S of an interference signal contained in the intermediate-frequency signal IF. It can also have a local oscillator control **102** which is designed for minimizing the frequency difference f_E between the estimated frequency f_S' of the interference signal and the center frequency f_{NM} of the stop band of the notch filter **15** (the difference would then be zero in the ideal case). For this purpose, the local oscillator control **102** adapts the frequencies of the local oscillator signals LO**1**, LO**2** in accordance with the frequency difference f_E determined. The spectral position of the intermediate-frequency band is in consequence variable and can be selected in such a manner that the interference signal IF_S always lies within the (predetermined) stop band of the notch filter **15**.

The circuit arrangement can be implemented partially digitally. For the digitization of the intermediate-frequency signal IF, an analog/digital converter **16** can be provided after the first mixer **11** in the direction of signal flow. For example, at least the control unit **10**, the second mixer **12** and the second local oscillator **14** are then implemented digitally. This reduces the needed hardware expenditure further.

The circuit arrangement can be used in a radio receiver. This can have an antenna and a radio-frequency receiving circuit connected to the antenna, which circuit provides the antenna signal received from the antenna as radio-frequency signal RF_IN for the circuit arrangement. Especially in the case of spread-spectrum receivers, a suppression of narrowband interference signals in the intermediate-frequency band is appropriate for improving the signal/noise ratio in the baseband signal. In this case, the received radio-frequency signal RF_IN can be a wideband, modulated spread-spectrum signal. In this case, the radio receiver can have a unit for despreading the baseband signal OUT. Band-spreading transmission methods can be applied, for example, in keyless access systems, especially in the motor vehicle field.

A further example embodiment provides a method for receiving a radio-frequency signal. The method comprises the following: Converting the radio-frequency signal RF_IN from a radio-frequency band into an intermediate-frequency band by mixing the radio-frequency signal with a first local oscillator signal LO**1** in order to thus obtain a corresponding intermediate-frequency signal IF; estimating an interference signal frequency f_S of an interference signal IF_S contained in the intermediate-frequency signal IF; filtering the intermediate-frequency signal IF with a notch filter **15** having a predeterminable stop band; and adapting the frequencies of the local oscillator signal LO**1** to the estimated frequency f_S of the interference signal in such a manner that the frequency f_S of the interference signal lies within the stop band of the notch filter. The filter characteristic of the notch filter **15** can be predetermined in this method and does not need to be adaptively adapted to the interference signal. The frequency estimation can be performed, especially in the intermediate-frequency band. However, a frequency estimation in the baseband or in the radio-frequency band is also possible. Filtering itself, however, is carried out in the intermediate-frequency band.

The method can also comprise the converting of the intermediate-frequency signal IF from the intermediate-frequency band into a baseband by means of a second local oscillator signal LO**2** in order to thus obtain a corresponding base band signal OUT. In the baseband, it is then possible to search for a useful signal and the data contained in the useful signal can be received if a useful signal has been found. If no useful signal is found, the above method steps can be repeated until a useful signal is detected. In the case of a spread-spectrum transmission, the searching for the useful signal comprises despreading the baseband signal by means of a known spreading sequence. A partially digital implementation of the method is possible. For example, the intermediate-frequency signal IF can be digitized before or after the filtering with the notch filter **15**.

All arrangements shown can be implemented as pure hardware or pure software applications or as a mixture of the two. The hardware can be designed to be analog, digital or mixed analog/digital, as required.

LIST OF REFERENCE SYMBOLS

10 Control unit
101 Interference-frequency estimator
102 Local oscillator control
11 Mixer
12 Mixer (multiplier)
13 Local oscillator
14 Local oscillator

15 Notch filter
16 Analog/digital converter
17 Anti-aliasing filter
RF_IN Radio-frequency input signal
IF Intermediate-frequency signal
IF_N Useful signal in the intermediate-frequency band
IF_S Interference signal in the intermediate-frequency band
OUT Baseband signal
f_{LO1}, f_{LO2} Frequencies of the local oscillators **13** and **14**, respectively
f_S Interference signal frequency
f_E Frequency difference
f_{NM} Notch filter center frequency
LO**1** Local oscillator signal with frequency f_{LO1}
LO**2** Local oscillator signal with frequency f_{LO2}
OSC_CTRL_1 Control signal for local oscillator **13**
OSC_CTRL_2 Control signal for local oscillator **14**

What is claimed is:

1. A circuit arrangement for suppressing interference signals with the aid of a band-stop filter, the circuit arrangement comprising:
a first local oscillator for generating a first local oscillator signal with an adjustable frequency and a second local oscillator for generating a second local oscillator signal with an adjustable frequency;
a first mixer for converting a radio-frequency signal into a corresponding intermediate-frequency signal using the first local oscillator signal with adjustable frequency;
a second mixer for converting the intermediate-frequency signal into a corresponding baseband signal using the second local oscillator signal with adjustable frequency;
a notch filter having a stop band defined by a predetermined frequency response; and
a control unit configured to:
estimate the frequency of an interference signal contained in the intermediate-frequency signal; and
control the first local oscillator to shift, over time, the frequency of the local oscillator signals generated by the first local oscillator and fed to the first mixer to match the estimated frequency of the interference signal such that the frequency of the interference signal lies within the stop band of the notch filter.

2. The circuit arrangement of claim **1**, wherein the control unit comprises:
a frequency estimator configured to estimate the frequency of an interference signal contained in the intermediate-frequency signal, and
a local oscillator control configured to determine the frequency difference between the estimated frequency and the center frequency of the stop band of the notch filter and adapt the frequencies of the local oscillator signals based on the determined frequency difference.

3. The circuit arrangement of claim **1**, further comprising an analog/digital converter downstream of the first mixer and configured to digitize the intermediate-frequency signal,
wherein at least the control unit, the second mixer, and the second local oscillator are implemented digitally.

4. The circuit arrangement of claim **1**, further comprising an antenna and a radio-frequency receiving circuit connected to the antenna and configured to provide as radio-frequency signal an antenna signal received from the antenna.

5. The circuit arrangement of claim **1**, wherein the received radio-frequency signal is a wideband, modulated spread-spectrum signal and wherein the circuit arrangement comprises a unit for despreading the baseband signal.

6. A method for receiving a radio-frequency signal, comprising:
converting the radio-frequency signal from an RF band into an intermediate-frequency band by mixing the radiofrequency signal with a first local oscillator signal at a mixer to obtain a corresponding intermediate-frequency signal;
estimating an interference signal frequency of an interference signal contained in the intermediate-frequency signal;
filtering the intermediate-frequency signal with a notch filter having a stop band; and
shifting the frequencies of the local oscillator signal input to the mixer over time until it is determined that the frequency of the local oscillator signal matches the estimated frequency of the interference signal such that the frequency of the interference signal lies within the stop band of the notch filter.

7. The method of claim **6**, further comprising:
converting the intermediate-frequency signal from the intermediate-frequency band into a baseband using a second local oscillator signal to obtain a corresponding baseband signal;
searching for a useful signal in the baseband signal; and
receiving the data contained in the useful signal when a useful signal has been found.

8. The method of claim **7**, further comprising repeating the converting, searching, and receiving steps when no useful signal is found.

9. The method of claim **7**, in which the searching for a useful signal in the baseband signal comprises;
despreading the baseband signal by means of a known spreading sequence.

10. The method of claim **6**, wherein the intermediate-frequency signal is digitized before or after the filtering with the notch filter.

11. The method of claim **6**, wherein the notch filter is inactive during the estimating of the interference-signal frequency.

12. A keyless access system, comprising:
a radio receiver comprising a circuit arrangement for suppressing interference signals with the aid of a band-stop filter, the circuit arrangement comprising:
a first local oscillator for generating a first local oscillator signal with an adjustable frequency and a second local oscillator for generating a second local oscillator signal with an adjustable frequency;
a first mixer for converting a radio-frequency signal into a corresponding intermediate-frequency signal using the first local oscillator signal with adjustable frequency;
a second mixer for converting the intermediate-frequency signal into a corresponding baseband signal using the second local oscillator signal with adjustable frequency;
a notch filter having a stop band defined by a predetermined frequency response; and
a control unit configured to:
estimate the frequency of an interference signal contained in the intermediate-frequency signal; and
control the first local oscillator to shift over time, the frequency of the local oscillator signals generated by the first local oscillator and fed to the first mixer to match the estimated frequency of the interference signal such that the frequency of the interference signal lies within the stop band of the notch filter.

13. The keyless access system of claim **12**, wherein the control unit comprises:

a frequency estimator configured to estimate the frequency of an interference signal contained in the intermediate-frequency signal, and

a local oscillator control configured to determine the frequency difference between the estimated frequency and the center frequency of the stop band of the notch filter and adapt the frequencies of the local oscillator signals based on the determined frequency difference.

14. The keyless access system of claim **12**, wherein the circuit arrangement of the radio receiver further comprises an analog/digital converter downstream of the first mixer and configured to digitize the intermediate-frequency signal,

wherein at least the control unit, the second mixer, and the second local oscillator are implemented digitally.

15. The keyless access system of claim **12**, wherein the circuit arrangement of the radio receiver further comprises an antenna and a radio-frequency receiving circuit connected to the antenna and configured to provide as radio-frequency signal an antenna signal received from the antenna.

16. The keyless access system of claim **12**, wherein the received radio-frequency signal is a wideband, modulated spread-spectrum signal and wherein the circuit arrangement comprises a unit for despreading the baseband signal.

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